

# STACK EMISSIONS MONITORING REPORT



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| Your contact at SOCOTEC UK LTD                                                                  |
|-------------------------------------------------------------------------------------------------|
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| Operator & Address:                                                                            |
|------------------------------------------------------------------------------------------------|
| Celtic Recycling<br>29-31 Clearwater Road<br>Queensway Meadows<br>Newport<br>Gwent<br>NP19 4ST |

| Permit Reference:        |
|--------------------------|
| EPR Permit: EPR/YP3135TE |

| Release Point: |
|----------------|
| A1 Shredder    |

| Sampling Date(s):  |
|--------------------|
| 15th December 2018 |

|                         |                                           |
|-------------------------|-------------------------------------------|
| SOCOTEC UK Job Number:  | LS0 171207                                |
| Report Date:            | 16th January 2018                         |
| Version:                | 1                                         |
| Report By:              | John Norvell                              |
| MCERTS Number:          | MM 02 126                                 |
| MCERTS Level:           | MCERTS Level 2 - Team Leader              |
| Technical Endorsements: | 1, 2, 3 & 4                               |
| Report Approved By:     | David May                                 |
| MCERTS Number:          | MM 07 862                                 |
| Business Title:         | MCERTS Level 2 - Operations Manager (LSO) |
| Technical Endorsements: | 1, 2, 3 & 4                               |
| Signature:              |                                           |



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## EXECUTIVE SUMMARY

### MONITORING OBJECTIVES

Celtic Recycling operates a shredding papered covered copper process at Newport which is subject to EPR Permit EPR/YP3135TE, under the Environmental Permitting Regulations 2010.

SOCOTEC UK LTD were commissioned by Celtic Recycling to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's EPR Permit, EPR/YP3135TE.

#### **Plant**

A1 Shredder

#### **Operator**

Celtic Recycling  
29-31 Clearwater Road  
Queensway Meadows  
Newport  
Gwent  
NP19 4ST

EPR Permit: EPR/YP3135TE

#### **Stack Emissions Monitoring Test House**

SOCOTEC UK - Cirencester Laboratory  
Units C & D  
Bankside Trade Park  
Cirencester  
GL7 1YT  
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.  
MCERTS accredited results will only be claimed where both the sampling and analytical stages are UKAS accredited.  
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## EXECUTIVE SUMMARY

| EMISSIONS SUMMARY                                |                    |        |                            |       |                          |
|--------------------------------------------------|--------------------|--------|----------------------------|-------|--------------------------|
| Parameter                                        | Units              | Result | Calculated Uncertainty +/- | Limit | MCERTS accredited result |
| Total Particulate Matter                         | mg/m <sup>3</sup>  | 0.38   | 0.75                       | 10    | ✓                        |
| Particulate Emission Rate                        | g/hr               | 5.10   | 10.20                      | -     |                          |
| Oil Mist                                         | mg/m <sup>3</sup>  | 0.150  | 0.153                      | -     | ✗                        |
| Oil Mist Emission Rate                           | g/hr               | 2.041  | 2.082                      | -     |                          |
| Moisture                                         | %                  | 1.2    | 0.04                       | -     | ✓                        |
| Stack Gas Temperature                            | °C                 | 10     | -                          | -     | ✓                        |
| Stack Gas Velocity                               | m/s                | 25.0   | 0.61                       | -     |                          |
| Gas Volumetric Flow Rate (Actual)                | m <sup>3</sup> /hr | 14343  | 737                        | -     |                          |
| Gas Volumetric Flow Rate (STP, Wet)              | m <sup>3</sup> /hr | 13706  | 705                        | -     |                          |
| Gas Volumetric Flow Rate (STP, Dry)              | m <sup>3</sup> /hr | 13535  | 696                        | -     |                          |
| Gas Volumetric Flow Rate at Reference Conditions | m <sup>3</sup> /hr | 13706  | 705                        | -     |                          |

ND = None Detected,

Results at or below the limit of detection are highlighted by bold italic text.

The above volumetric flow rate is calculated using data from the preliminary survey. Mass emissions for non isokinetic tests are calculated using these values. For all isokinetic testing the mass emission is calculated using test specific flow data and not the above values.

Reference conditions are 273K, 101.3kPa without correction for water vapour

## EXECUTIVE SUMMARY

| MONITORING TIMES               |                  |                |                   |
|--------------------------------|------------------|----------------|-------------------|
| Parameter                      | Sampling Date(s) | Sampling Times | Sampling Duration |
| Total Particulate Matter Run 1 | 15 December 2017 | 09:48 - 10:48  | 60 minutes        |
| Oil Mist Run 1                 | 15 December 2017 | 09:48 - 10:48  | 60 minutes        |
| Preliminary Stack Traverse     | 15 December 2017 | 09:00          | -                 |

## EXECUTIVE SUMMARY

### PROCESS DETAILS

| Parameter                                     | Process Details                  |
|-----------------------------------------------|----------------------------------|
| Description of process                        | Shredding papered covered copper |
| Continuous or batch                           | Batch                            |
| Product Details                               | Shredded clean copper            |
| Part of batch to be monitored (if applicable) | Representative 1 Hr period       |
| Normal load, throughput or continuous rating  | Normal                           |
| Fuel used during monitoring                   | None                             |
| Abatement                                     | Bag filter                       |
| Plume Appearance                              | None                             |

## EXECUTIVE SUMMARY

### Monitoring Methods

The selection of standard reference / alternative methods employed by SOCOTEC UK is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Note (Monitoring) M2.

| MONITORING METHODS      |                                                             |                                      |                    |                                |                                |                           |
|-------------------------|-------------------------------------------------------------|--------------------------------------|--------------------|--------------------------------|--------------------------------|---------------------------|
| Species                 | Method<br>Standard Reference Method /<br>Alternative Method | SOCOTEC UK<br>Technical<br>Procedure | UKAS Lab<br>Number | MCERTS<br>Accredited<br>Method | Limit of<br>Detection<br>(LOD) | Calculated<br>MU<br>+/- % |
| TPM                     | SRM - BS EN 13284-1                                         | AE 104                               | 1015               | Yes                            | 0.38 mg/m <sup>3</sup>         | 200%                      |
| Oil Mist                | SRM - BS EN 13284-1 / MDHS 84                               | AE 061                               | 1015               | No                             | 0.007 mg/m <sup>3</sup>        | 102%                      |
| H <sub>2</sub> O        | SRM - BS EN 14790                                           | AE 105                               | 1015               | Yes                            | 0.01%                          | 3.25%                     |
| Velocity                | SRM - BS EN ISO 16911-1                                     | AE 154                               | 1015               | Yes                            | 5 Pa                           | 2.44%                     |
| Volumetric Flow<br>Rate | SRM - BS EN ISO 16911-1                                     | AE 154                               | 1015               | Yes                            | -                              | 5.14%                     |

BS EN 14790 has been validated over a range of 4 - 40%. It is however the preferred method of the Environment Agency for concentrations below 4%

## EXECUTIVE SUMMARY

### Analytical Methods

The following tables list the analytical methods employed together with the custody and archiving details:

| SAMPLING METHODS WITH SUBSEQUENT ANALYSIS |                      |                      |                 |                              |                            |                            |                |
|-------------------------------------------|----------------------|----------------------|-----------------|------------------------------|----------------------------|----------------------------|----------------|
| Species                                   | Analytical Technique | Analytical Procedure | UKAS Lab Number | UKAS Accredited Lab Analysis | Analysis Lab               | Sample Archive Location    | Archive Period |
| TPM                                       | Gravimetric          | AE 106               | 1015            | Yes                          | SOCOTEC UK - (Cirencester) | SOCOTEC UK - (Cirencester) | 8 Weeks        |
| Oil Mist                                  | GC/FID               | SOP                  | N/A             | No                           | SAL                        | SAL                        | 8 Weeks        |

Please note, at least one of the metals analysed fall outside of the labs UKAS accreditation. For an individual breakdown please refer to the metals summary in appendix 2

| ON-SITE TESTING  |                      |                      |                 |                            |                            |                       |                |
|------------------|----------------------|----------------------|-----------------|----------------------------|----------------------------|-----------------------|----------------|
| Species          | Analytical Technique | Analytical Procedure | UKAS Lab Number | MCERTS Accredited Analysis | Laboratory                 | Data Archive Location | Archive Period |
| H <sub>2</sub> O | Gravimetric          | AE 105               | 1015            | Yes                        | SOCOTEC UK - (Cirencester) | -                     | -              |

## EXECUTIVE SUMMARY

| SAMPLING LOCATION                              |        |            |                     |           |             |
|------------------------------------------------|--------|------------|---------------------|-----------|-------------|
| Sampling Plane Validation Criteria             | Value  | Units      | Requirement         | Compliant | Method      |
| Lowest Differential Pressure                   | 500    | Pa         | $\geq 5 \text{ Pa}$ | Yes       | BS EN 15259 |
| Lowest Gas Velocity                            | 24.1   | m/s        | -                   | -         | -           |
| Highest Gas Velocity                           | 26.1   | m/s        | -                   | -         | -           |
| Ratio of Gas Velocities                        | 1.1    | : 1        | $< 3 : 1$           | Yes       | BS EN 15259 |
| Mean Velocity                                  | 25.0   | m/s        | -                   | -         | -           |
| Maximum angle of flow with regard to duct axis | $< 15$ | $^{\circ}$ | $< 15^{\circ}$      | Yes       | BS EN 15259 |
| No local negative flow                         | Yes    | -          | -                   | Yes       | BS EN 15259 |

| DUCT CHARACTERISTICS |          |                |
|----------------------|----------|----------------|
|                      | Value    | Units          |
| Shape                | Circular | -              |
| Depth                | 0.45     | m              |
| Width                | -        | m              |
| Area                 | 0.16     | m <sup>2</sup> |
| Port Depth           | 90       | mm             |

| SAMPLING LINES & POINTS |            |                 |
|-------------------------|------------|-----------------|
|                         | Isokinetic | Non-Iso & Gases |
| Sample port size        | 3"         | -               |
| Number of lines used    | 1          | -               |
| Number of points / line | 4          | -               |
| Duct orientation        | vertical   | -               |
| Filtration for TPM      | Quartz     | -               |

| SAMPLING PLATFORM                                                  |           |
|--------------------------------------------------------------------|-----------|
| General Platform Information                                       |           |
| Permanent / Temporary Platform / Ground level / Floor Level / Roof | Permanent |
| Inside / Outside                                                   | Outside   |

| M1 Platform requirements                                                           |     |
|------------------------------------------------------------------------------------|-----|
| Is there a sufficient working area so work can be performed in a compliant manner  | Yes |
| Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)              | Yes |
| Platform has vertical base boards (approximately 0.25 m high)                      | Yes |
| Platform has removable chains / self closing gates at the top of ladders           | No  |
| Handrail / obstructions do not hamper insertion of sampling equipment              | No  |
| Depth of Platform = $\geq$ Stack depth / diameter + wall and port thickness + 1.5m | Yes |

### Sampling Platform Improvement Recommendations (if applicable)

The sampling location meets all the requirements as specified in EA Guidance Note M1.

## EXECUTIVE SUMMARY

### Sampling & Analytical Method Deviations

#### **Single port**

Only one line available for sampling, however the number of sampling points were doubled in line with the standard reference method.

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APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

APPENDIX 3 - Measurement Uncertainty Budget Calculations

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

| MONITORING SCHEDULE |                                                             |                                      |                    |                                |                      |
|---------------------|-------------------------------------------------------------|--------------------------------------|--------------------|--------------------------------|----------------------|
| Species             | Method<br>Standard Reference Method /<br>Alternative Method | SOCOTEC UK<br>Technical<br>Procedure | UKAS Lab<br>Number | MCERTS<br>Accredited<br>Method | Number of<br>Samples |
| TPM                 | SRM - BS EN 13284-1                                         | AE 104                               | 1015               | Yes                            | 1                    |
| Oil Mist            | SRM - BS EN 13284-1 / MDHS 84                               | AE 061                               | 1015               | No                             | 1                    |
| H <sub>2</sub> O    | SRM - BS EN 14790                                           | AE 105                               | 1015               | Yes                            | 1                    |
| Velocity            | SRM - BS EN ISO 16911-1                                     | AE 154                               | 1015               | Yes                            | 1                    |

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

| CALIBRATEABLE EQUIPMENT CHECKLIST |                |                                 |                |                           |                |
|-----------------------------------|----------------|---------------------------------|----------------|---------------------------|----------------|
| Extractive Sampling               |                | Instrumental Analyser/s         |                | Miscellaneous             |                |
| Equipment                         | Equipment I.D. | Equipment                       | Equipment I.D. | Equipment                 | Equipment I.D. |
| Control Box DGM                   | P330           | Horiba PG-250 Analyser          | -              | Laboratory Balance        | P66            |
| Box Thermocouples                 | P330           | FT-IR Gasmeter                  | -              | Tape Measure              | P1758          |
| Meter In Thermocouple             | P330           | FT-IR Oven Box                  | -              | Stopwatch                 | P2314          |
| Meter Out Thermocouple            | P330           | Bernath 3006 FID                | -              | Protractor                |                |
| Control Box Timer                 | P330           | Signal 3030 FID                 | -              | Barometer                 | P341           |
| Oven Box                          | -              | Servomex                        | -              | Digital Micromanometer    | P1909          |
| Probe                             | -              | JCT Heated Head Filter          | -              | Digital Temperature Meter | -              |
| Probe Thermocouple                | P1448          | Thermo FID                      | -              | Stack Thermocouple        | P1448          |
| Probe                             | -              | Stackmaster                     | -              | Mass Flow Controller      | -              |
| Probe Thermocouple                | -              | FTIR Heater Box for Heated Line | -              | MFC Display module        | -              |
| S-Pitot                           | P2113/0.84     | Anemometer                      | -              | 1m Heated Line (1)        | -              |
| L-Pitot                           | -              | Ecophysix NOx Analyser          | -              | 1m Heated Line (2)        | -              |
| Site Balance                      | -              | Chiller (JCT/MAK 10)            | -              | 1m Heated Line (3)        | -              |
| Last Impinger Arm                 | -              | Heated Line Controller (1)      | -              | 5m Heated Line (1)        | -              |
| Dioxins Cond. Thermocouple        | -              | Heated Line Controller (2)      | -              | 10m Heated Line (1)       | -              |
| Callipers                         | -              | Site temperature Logger         | -              | 10m Heated Line (2)       | -              |
| Small DGM                         | -              |                                 | -              | 15m Heated Line (1)       | -              |
| Heater Controller                 | -              |                                 | -              | 20m Heated Line (1)       | -              |
| Inclinometer (Swirl Device)       | P2372          |                                 | -              | 20m Heated Line (2)       | -              |

NOTE: If the equipment I.D is represented by a dash (-), then this piece of equipment has not been used for this test.

| CALIBRATION GASES            |                     |          |     |   |                            |
|------------------------------|---------------------|----------|-----|---|----------------------------|
| Gas (traceable to ISO 17025) | Cylinder I.D Number | Supplier | ppm | % | Analytical Tolerance +/- % |
| -                            | -                   | -        | -   | - | -                          |

**STACK EMISSIONS MONITORING TEAM**

| MONITORING TEAM |               |                |        |                                         |        |        |        |        |
|-----------------|---------------|----------------|--------|-----------------------------------------|--------|--------|--------|--------|
| Personnel       | MCERTS Number | MCERTS         |        | TE / H&S Qualifications and Expiry Date |        |        |        |        |
|                 |               | Level          | Expiry | TE1                                     | TE2    | TE3    | TE4    | H&S    |
| John Norvell    | MM 02 126     | MCERTS Level 2 | Sep-22 | Jun-18                                  | Jun-18 | Mar-19 | Dec-18 | Sep-22 |
| Stephen Huntley | MM 02 081     | MCERTS Level 2 | Sep-22 | Mar-22                                  | Mar-22 | Mar-22 | Nov-18 | Sep-22 |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| TOTAL PARTICULATE MATTER SUMMARY |                                   |                                    |                                  |                            |                       |
|----------------------------------|-----------------------------------|------------------------------------|----------------------------------|----------------------------|-----------------------|
| Parameter                        | Sampling Times                    | Concentration<br>mg/m <sup>3</sup> | Uncertainty<br>mg/m <sup>3</sup> | Limit<br>mg/m <sup>3</sup> | Emission<br>Rate g/hr |
| Run 1                            | 09:48 - 10:48<br>15 December 2017 | 0.38                               | 0.75                             | 10                         | 5                     |
| Blank                            | -                                 | 0.45                               | -                                | -                          | -                     |

Reference conditions are 273K, 101.3kPa without correction for water vapour

| Acetone Blank Value<br>mg/l | Acceptable Value<br>mg/l |
|-----------------------------|--------------------------|
| 2.0                         | 10                       |

**FILTER INFORMATION**

| SAMPLES |                                |                             |                           |                               |                                  |                                |                              |                                    |
|---------|--------------------------------|-----------------------------|---------------------------|-------------------------------|----------------------------------|--------------------------------|------------------------------|------------------------------------|
| Test    | Filter & Probe<br>Rinse Number | Filter Start<br>Weight<br>g | Filter End<br>Weight<br>g | Mass Gained<br>on Filter<br>g | Probe Rinse<br>Start Weight<br>g | Probe Rinse<br>End Weight<br>g | Mass Gained on<br>Probe<br>g | Combined Total<br>Mass Gained<br>g |
| Run 1   | 310225                         | 0.15060                     | 0.15050                   | -0.00010                      | 74.87090                         | 74.87110                       | 0.00020                      | 0.00050                            |

If total mass gained is less than the LOD then the LOD is reported

| BLANKS |                          |                             |                           |                            |                            |                          |                           |                                    |
|--------|--------------------------|-----------------------------|---------------------------|----------------------------|----------------------------|--------------------------|---------------------------|------------------------------------|
| Test   | Filter & Probe<br>Number | Filter Start<br>Weight<br>g | Filter End<br>Weight<br>g | Mass Gained<br>Filter<br>g | Probe Start<br>Weight<br>g | Probe End<br>Weight<br>g | Mass Gained<br>Probe<br>g | Combined Total<br>Mass Gained<br>g |
| Run 1  | 310224                   | 0.15450                     | 0.15460                   | 0.00010                    | 74.75060                   | 74.75110                 | 0.00050                   | 0.00060                            |

If total mass gained is less than the LOD then the LOD is reported

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| ISOKINETIC SAMPLING EQUATIONS - RUN 1                                                                   |                     |                                                                              |  | TPM |  |
|---------------------------------------------------------------------------------------------------------|---------------------|------------------------------------------------------------------------------|--|-----|--|
| <b>Absolute pressure of stack gas, P<sub>s</sub></b>                                                    |                     |                                                                              |  |     |  |
| Barometric pressure, P <sub>b</sub>                                                                     | mm Hg               | 750.76                                                                       |  |     |  |
| Stack static pressure, P <sub>static</sub>                                                              | mm H <sub>2</sub> O | 14.79                                                                        |  |     |  |
| P <sub>s</sub> = P <sub>b</sub> + (P <sub>static</sub> )                                                | mm Hg               | 751.84                                                                       |  |     |  |
|                                                                                                         |                     | 13.6                                                                         |  |     |  |
| <b>Vol. of water vapour collected, V<sub>wstd</sub></b>                                                 |                     |                                                                              |  |     |  |
| Moisture trap weight increase, V <sub>lc</sub>                                                          | g                   | 13.3                                                                         |  |     |  |
| V <sub>wstd</sub> = (0.001246)(V <sub>lc</sub> )                                                        | m <sup>3</sup>      | 0.0165718                                                                    |  |     |  |
| <b>Volume of gas metered dry, V<sub>mstd</sub></b>                                                      |                     |                                                                              |  |     |  |
| Volume of gas sample through gas meter, V <sub>m</sub>                                                  |                     | 1.384                                                                        |  |     |  |
| Gas meter correction factor, V <sub>d</sub>                                                             |                     | 1.018                                                                        |  |     |  |
| Mean dry gas meter temperature, T <sub>m</sub>                                                          |                     | 17.667                                                                       |  |     |  |
| Mean pressure drop across orifice, DP, mmH <sub>2</sub> O                                               |                     | 47.279                                                                       |  |     |  |
| V <sub>mstd</sub> = (0.3592)(V <sub>m</sub> )(P <sub>b</sub> + (DP/13.6))(Y <sub>d</sub> )              |                     | 1.313                                                                        |  |     |  |
|                                                                                                         |                     | T <sub>m</sub> + 273                                                         |  |     |  |
| <b>Volume of gas metered wet, V<sub>mstw</sub></b>                                                      |                     |                                                                              |  |     |  |
| V <sub>mstw</sub> = V <sub>mstd</sub> + V <sub>wstd</sub>                                               | m <sup>3</sup>      | 1.3298                                                                       |  |     |  |
| <b>Vol. of gas metered at O<sub>2</sub> Ref. Cond., V<sub>mstd@X%O<sub>2</sub></sub></b>                |                     |                                                                              |  |     |  |
| Is the process burning hazardous waste? (If yes, no favourable oxygen correction)                       |                     | No                                                                           |  |     |  |
| % oxygen measured in gas stream, act%O <sub>2</sub>                                                     |                     | 20.9                                                                         |  |     |  |
| % oxygen reference condition                                                                            |                     | 21                                                                           |  |     |  |
| O <sub>2</sub> Reference O <sub>2</sub> Ref = 21.0 - act%O <sub>2</sub>                                 |                     | No O2 Ref                                                                    |  |     |  |
| Factor 21.0 - ref%O <sub>2</sub>                                                                        |                     |                                                                              |  |     |  |
| V <sub>mstd@X%oxygen</sub> = (V <sub>mstd</sub> ) (O <sub>2</sub> Ref)                                  | m <sup>3</sup>      | No O2 Ref                                                                    |  |     |  |
| <b>Moisture content, B<sub>wo</sub></b>                                                                 |                     |                                                                              |  |     |  |
| B <sub>wo</sub> = V <sub>wstd</sub>                                                                     |                     | 0.0125                                                                       |  |     |  |
| V <sub>mstd</sub> + V <sub>wstd</sub>                                                                   | %                   | 1.25                                                                         |  |     |  |
| <b>Moisture by FTIR</b>                                                                                 |                     |                                                                              |  |     |  |
|                                                                                                         | %                   | -                                                                            |  |     |  |
| <b>Velocity of stack gas, V<sub>s</sub></b>                                                             |                     |                                                                              |  |     |  |
| Pitot tube velocity constant, K <sub>p</sub>                                                            |                     | 34.97                                                                        |  |     |  |
| Velocity pressure coefficient, C <sub>p</sub>                                                           |                     | 0.84                                                                         |  |     |  |
| Mean of velocity heads, DP <sub>avg</sub>                                                               | mm H <sub>2</sub> O | 54.50                                                                        |  |     |  |
| Mean square root of velocity heads, ÖDP                                                                 |                     | 7.38                                                                         |  |     |  |
| Mean stack gas temperature, T <sub>s</sub>                                                              | °C                  | 10                                                                           |  |     |  |
| V <sub>s</sub> = (K <sub>p</sub> )(C <sub>p</sub> )(ÖDP)(Ö(T <sub>s</sub> + 273))                       | m/s                 | 24.83                                                                        |  |     |  |
|                                                                                                         |                     | (M <sub>s</sub> )(P <sub>s</sub> )                                           |  |     |  |
| <b>Molecular weight of dry gas, M<sub>d</sub></b>                                                       |                     |                                                                              |  |     |  |
| CO <sub>2</sub>                                                                                         | %                   | 0.03                                                                         |  |     |  |
| O <sub>2</sub>                                                                                          | %                   | 20.90                                                                        |  |     |  |
| Total                                                                                                   | %                   | 20.93                                                                        |  |     |  |
| N <sub>2</sub> (100 - Total)                                                                            | %                   | 79.07                                                                        |  |     |  |
| M <sub>d</sub> = 0.44(%CO <sub>2</sub> ) + 0.32(%O <sub>2</sub> ) + 0.28(%N <sub>2</sub> )              |                     | 28.84                                                                        |  |     |  |
| <b>Molecular weight of wet gas, M<sub>s</sub></b>                                                       |                     |                                                                              |  |     |  |
| M <sub>s</sub> = M <sub>d</sub> (1 - B <sub>wo</sub> ) + 18(B <sub>wo</sub> )                           | g/gmol              | 28.71                                                                        |  |     |  |
| <b>Actual flow of stack gas, Q<sub>a</sub></b>                                                          |                     |                                                                              |  |     |  |
| Area of stack, A <sub>s</sub>                                                                           | m <sup>2</sup>      | 0.16                                                                         |  |     |  |
| Q <sub>a</sub> = (60)(A <sub>s</sub> )(V <sub>s</sub> )                                                 | m <sup>3</sup> /min | 237.0                                                                        |  |     |  |
| <b>Total flow of stack gas, Q</b>                                                                       |                     |                                                                              |  |     |  |
| Conversion factor (K/mm.Hg)                                                                             |                     | 0.3592                                                                       |  |     |  |
| Q <sub>std</sub> = (Q <sub>a</sub> )P <sub>s</sub> (0.3592)(1 - B <sub>wo</sub> )                       | Dry                 | 223.3                                                                        |  |     |  |
|                                                                                                         |                     | (T <sub>s</sub> ) + 273                                                      |  |     |  |
| Q <sub>stdO2</sub> = (Q <sub>a</sub> )P <sub>s</sub> (0.3592)(1 - B <sub>wo</sub> )(O <sub>2</sub> REF) | @O <sub>2</sub> ref | No O2 Ref                                                                    |  |     |  |
|                                                                                                         |                     | (T <sub>s</sub> ) + 273                                                      |  |     |  |
| Q <sub>stw</sub> = (Q <sub>a</sub> )P <sub>s</sub> (0.3592)                                             | Wet                 | 226.16                                                                       |  |     |  |
|                                                                                                         |                     | (T <sub>s</sub> ) + 273                                                      |  |     |  |
| <b>Percent isokinetic, %I</b>                                                                           |                     |                                                                              |  |     |  |
| Nozzle diameter, D <sub>n</sub>                                                                         | mm                  | 4.38                                                                         |  |     |  |
| Nozzle area, A <sub>n</sub>                                                                             | mm <sup>2</sup>     | 15.07                                                                        |  |     |  |
| Total sampling time, q                                                                                  | min                 | 60                                                                           |  |     |  |
| %I = (4.6398E6)(T <sub>s</sub> + 273)(V <sub>mstd</sub> )                                               | %                   | 103.4                                                                        |  |     |  |
|                                                                                                         |                     | (P <sub>s</sub> )(V <sub>s</sub> )(A <sub>n</sub> )(q)(1 - B <sub>wo</sub> ) |  |     |  |
| Acceptable isokinetic range 95% to 115%                                                                 |                     | Yes                                                                          |  |     |  |
| <b>Particulate Concentration, C</b>                                                                     |                     |                                                                              |  |     |  |
| Mass collected on filter, M <sub>f</sub>                                                                | g                   | -0.00010                                                                     |  |     |  |
| Mass collected in probe, M <sub>p</sub>                                                                 | g                   | 0.00020                                                                      |  |     |  |
| Total mass collected, M <sub>n</sub>                                                                    | g                   | 0.00050                                                                      |  |     |  |
| C <sub>wet</sub> = M <sub>n</sub>                                                                       | mg/m <sup>3</sup>   | 0.376                                                                        |  |     |  |
|                                                                                                         |                     | V <sub>mstw</sub>                                                            |  |     |  |
| C <sub>dry</sub> = M <sub>n</sub>                                                                       | mg/m <sup>3</sup>   | 0.381                                                                        |  |     |  |
|                                                                                                         |                     | V <sub>mstd</sub>                                                            |  |     |  |
| C <sub>dry@X%O2</sub> = M <sub>n</sub>                                                                  | mg/m <sup>3</sup>   | No O2 Ref                                                                    |  |     |  |
|                                                                                                         |                     | V <sub>mstd@X%oxygen</sub>                                                   |  |     |  |
| <b>Particulate Emission Rates, E</b>                                                                    |                     |                                                                              |  |     |  |
| E = [(C <sub>wet</sub> )(Q <sub>stw</sub> )(60)] / 1000                                                 |                     | 5.10                                                                         |  |     |  |

As the total mass gained was less than the LOD, the LOD has been reported

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**TOTAL PARTICULATE MATTER QUALITY ASSURANCE CHECKLIST**

| LEAK RATE |                                 |                                     |                                      |                         |                                   |                        |
|-----------|---------------------------------|-------------------------------------|--------------------------------------|-------------------------|-----------------------------------|------------------------|
| Run       | Mean Sampling Rate<br>litre/min | Pre-sampling Leak Rate<br>litre/min | Post-sampling Leak Rate<br>litre/min | Maximum Vacuum<br>mm Hg | Acceptable Leak Rate<br>litre/min | Leak Tests Acceptable? |
| Run 1     | 23.48                           | 0.14                                | 0.15                                 | -381                    | 0.47                              | Yes                    |

| ISOKINETICITY |                           |                          |
|---------------|---------------------------|--------------------------|
| Run           | Isokinetic Variation<br>% | Acceptable Isokineticity |
| Run 1         | 103.44                    | Yes                      |

Acceptable isokinetic range 95% to 115%

| WEIGHING BALANCE UNCERTAINTY |                             |                             |              |
|------------------------------|-----------------------------|-----------------------------|--------------|
| Run                          | Result<br>mg/m <sup>3</sup> | 5% ELV<br>mg/m <sup>3</sup> | LOD < 5% ELV |
| Run 1                        | 0.38                        | 0.5                         | Yes          |

The above is based on both the Filter and rinse uncertainty

| BLANK VALUE |                                          |                                                 |                                             |                                               |
|-------------|------------------------------------------|-------------------------------------------------|---------------------------------------------|-----------------------------------------------|
| Run         | Overall Blank Value<br>mg/m <sup>3</sup> | Daily Emission Limit Value<br>mg/m <sup>3</sup> | Acceptable Blank Value<br>mg/m <sup>3</sup> | Overall Blank Acceptable<br>mg/m <sup>3</sup> |
| Blank 1     | 0.45                                     | 10                                              | 1.0                                         | Yes                                           |

| FILTERS |                 |                   |                                  |                                               |                                                |
|---------|-----------------|-------------------|----------------------------------|-----------------------------------------------|------------------------------------------------|
| Run     | Filter Material | Filter Size<br>mm | Max Filtration Temperature<br>°C | Pre-use Filter Conditioning Temperature<br>°C | Post-use Filter Conditioning Temperature<br>°C |
| Run 1   | Quartz Fibre    | 47                | 10                               | 180                                           | 160                                            |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**OIL MIST SUMMARY**

| OIL MIST    |                                   |                                    |                          |                            |                       |
|-------------|-----------------------------------|------------------------------------|--------------------------|----------------------------|-----------------------|
| Test        | Sampling Times                    | Concentration<br>mg/m <sup>3</sup> | LOD<br>mg/m <sup>3</sup> | Limit<br>mg/m <sup>3</sup> | Emission<br>Rate g/hr |
| Run 1       | 09:48 - 10:48<br>15 December 2017 | 0.1504                             | 0.007                    | -                          | 2.04                  |
| Field Blank | -                                 | 0.0752                             | -                        | -                          | -                     |

Reference conditions are 273K, 101.3kPa without correction for water vapour

| OIL MIST                      | PARTICULATE PHASE              |                            |                                    | VAPOUR PHASE                   |                            |                                    |
|-------------------------------|--------------------------------|----------------------------|------------------------------------|--------------------------------|----------------------------|------------------------------------|
|                               | Stack LOD<br>mg/m <sup>3</sup> | Laboratory<br>Result<br>ug | Concentration<br>mg/m <sup>3</sup> | Stack LOD<br>mg/m <sup>3</sup> | Laboratory<br>Result<br>ug | Concentration<br>mg/m <sup>3</sup> |
| Oil Mist                      | 0.07520                        | 200                        | 0.15040                            | -                              | -                          | -                                  |
| Volume Sampled m <sup>3</sup> |                                | 1.3298                     |                                    |                                |                            | -                                  |

Reference conditions are 273K, 101.3kPa without correction for water vapour

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

| ISOKINETIC SAMPLING EQUATIONS RUN 1                                                  |                       |                       |  | OIL MIST                                             |                                           |
|--------------------------------------------------------------------------------------|-----------------------|-----------------------|--|------------------------------------------------------|-------------------------------------------|
| <b>Absolute pressure of stack gas, <math>P_s</math></b>                              |                       |                       |  | <b>Molecular weight of dry gas, <math>M_d</math></b> |                                           |
| Barometric pressure, $P_b$                                                           | mm Hg                 | 750.8                 |  | CO <sub>2</sub>                                      | % 0.03                                    |
| Stack static pressure, $P_{static}$                                                  | mm H <sub>2</sub> O   | 14.8                  |  | O <sub>2</sub>                                       | % 20.90                                   |
| $P_s = P_b + (P_{static})$                                                           | mm Hg                 |                       |  | Total                                                | % 20.93                                   |
| 13.6                                                                                 |                       | 751.8                 |  | N <sub>2</sub> (100 - Total)                         | % 79.07                                   |
|                                                                                      |                       |                       |  | $M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%N_2)$     | 28.84                                     |
| <b>Vol. of water vapour collected, <math>V_{wstd}</math></b>                         |                       |                       |  | <b>Molecular weight of wet gas, <math>M_s</math></b> |                                           |
| Moisture trap weight increase, $V_{lc}$                                              | g                     | -                     |  | $M_s = M_d(1 - B_{wo}) + 18(B_{wo})$                 | g/gmol 28.71                              |
| $V_{wstd} = (0.001246)(V_{lc})$                                                      | m <sup>3</sup>        | -                     |  | <b>Velocity of stack gas, <math>V_s</math></b>       |                                           |
| <b>Volume of gas metered dry, <math>V_{mstd}</math></b>                              |                       |                       |  | Pitot tube velocity constant, $K_p$                  | 34.97                                     |
| Volume of gas sample through gas meter, $V_m$                                        |                       | 1.384                 |  | Velocity pressure coefficient, $C_p$                 | 0.84                                      |
| Gas meter correction factor, $Y_d$                                                   |                       | 1.018                 |  | Mean of velocity heads, $DP_{avg}$                   | mm H <sub>2</sub> O 54.50                 |
| Mean dry gas meter temperature, $T_m$                                                |                       | 17.67                 |  | Mean square root of velocity heads, $\sqrt{ODP}$     | 7.38                                      |
| Mean pressure drop across orifice, $DH$                                              | mm                    | 47.28                 |  | Mean stack gas temperature, $T_s$                    | °C 10                                     |
|                                                                                      |                       |                       |  | $V_s = (K_p)(C_p)(\sqrt{ODP})(\sqrt{(T_s + 273)})$   | m/s 24.83                                 |
| $V_{mstd} = (0.3592)(V_m)(P_b + (DH/13.6))(Y_d)$                                     |                       | 1.31                  |  | <b>Actual flow of stack gas, <math>Q_a</math></b>    |                                           |
| $T_m + 273$                                                                          |                       |                       |  | Area of stack, $A_s$                                 | m <sup>2</sup> 0.16                       |
| <b>Volume of gas metered wet, <math>V_{mstw}</math></b>                              |                       |                       |  | $Q_a = (60)(A_s)(V_s)$                               | m <sup>3</sup> /min 237.0                 |
| $V_{mstw} = V_{mstd} + V_{wstd}$                                                     | m <sup>3</sup>        | 1.3298                |  | <b>Total flow of stack gas, <math>Q</math></b>       |                                           |
| <b>Vol. of gas metered at O<sub>2</sub> Ref. Cond., <math>V_{mstd@X\%O_2}</math></b> |                       |                       |  | Conversion factor (K/mm.Hg)                          | 0.3592                                    |
| Is the process burning hazardous waste? (If yes, no favourable oxygen correction)    | No                    |                       |  | $Q_{std} = (Q_a)P_s(0.3592)(1 - B_{wo})$             | Dry 223.3                                 |
| % oxygen measured in gas stream, act%O <sub>2</sub>                                  | 20.9                  |                       |  | $Q_{stdO_2} = (Q_a)P_s(0.3592)(1 - B_{wo})(O_2REF)$  | @O <sub>2</sub> ref No O <sub>2</sub> Ref |
| % oxygen reference condition                                                         | 21                    |                       |  | $Q_{stw} = (Q_a)P_s(0.3592)$                         | Wet 226.2                                 |
| O <sub>2</sub> Reference O <sub>2</sub> Ref = 21.0 - act%O <sub>2</sub>              | No O <sub>2</sub> Ref |                       |  | <b>Percent isokinetic, %I</b>                        |                                           |
| Factor 21.0 - ref%O <sub>2</sub>                                                     | No O <sub>2</sub> Ref |                       |  | Nozzle diameter, $D_n$                               | mm 4.38                                   |
| $V_{mstd@X\%oxygen} = (V_{mstd}) (O_2 Ref)$                                          | m <sup>3</sup>        | No O <sub>2</sub> Ref |  | Nozzle area, $A_n$                                   | mm <sup>2</sup> 15.07                     |
| <b>Moisture content, <math>B_{wo}</math></b>                                         |                       |                       |  | Total sampling time, $q$                             | min 60                                    |
| $B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$                                      | %                     | 0.0125                |  | %I = $(4.6398E6)(T_s + 273)(V_{mstd})$               | % 103.4                                   |
|                                                                                      |                       | 1.25                  |  | $(P_s)(V_s)(A_n)(q)(1 - B_{wo})$                     |                                           |
| <b>Moisture by FTIR</b>                                                              |                       |                       |  | Acceptable isokinetic range 95% to 115%              | Yes                                       |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**OIL MIST QA CHECKLIST**

| Leak Test Results | Mean Sampling Rate<br>litre/min | Pre-sampling Leak Rate<br>litre/min | Post-sampling Leak Rate<br>litre/min | Maximum Vacuum<br>mm Hg | Acceptable Leak Rate<br>litre/min | Leak Tests Acceptable<br>litre/min |
|-------------------|---------------------------------|-------------------------------------|--------------------------------------|-------------------------|-----------------------------------|------------------------------------|
| Run 1             | 23.5                            | 0.14                                | 0.15                                 | -381                    | 0.47                              | Yes                                |

| Isokinetic Criterion Compliance | Isokinetic Variation<br>% | Acceptable Isokineticity |
|---------------------------------|---------------------------|--------------------------|
| Run 1                           | 103.4                     | Yes                      |

| Filtration / Temp | Filter Material | Filter Size<br>mm | Maximum Filtration Temperature<br>°C | Maximum storage / transit Temperature<br>°C |
|-------------------|-----------------|-------------------|--------------------------------------|---------------------------------------------|
| Run 1             | Quartz Fibre    | 47                | 10                                   | 15                                          |

| Metals | Type of Absorbers - Metals | Absorption Solutions - Metals |
|--------|----------------------------|-------------------------------|
| Run 1  | Quartz Filter              | None                          |

### MOISTURE CALCULATIONS

| Moisture Determination - Isokinetic |                                   |              |            |            |               |     |             |
|-------------------------------------|-----------------------------------|--------------|------------|------------|---------------|-----|-------------|
| Test Number                         | Sampling Time and Date            | Start Weight | End Weight | Total gain | Concentration | LOD | Uncertainty |
|                                     |                                   | kg           | kg         | kg         | %             | %   | %           |
| Run 1                               | 09:48 - 10:48<br>15 December 2017 | 2.8964       | 2.9097     | 0.0133     | 1.2           | 0.0 | 3.3         |

| Moisture Quality Assurance |                   |                      |               |                 |               |                      |                        |
|----------------------------|-------------------|----------------------|---------------|-----------------|---------------|----------------------|------------------------|
| Test Number                | Sampling Duration | Total Volume Sampled | Sampling Rate | Start Leak Rate | End Leak Rate | Acceptable Leak Rate | Leak Tests Acceptable? |
|                            | mins              | l                    | l/min         | l/min           | l/min         | l/min                |                        |
| Run 1                      | 60                | 1330                 | 23.5          | 0.140           | 0.150         | 0.470                | Yes                    |

### PRELIMINARY STACK SURVEY

| Stack Characteristics         |       |                |
|-------------------------------|-------|----------------|
| Stack Diameter / Depth, D     | 0.45  | m              |
| Stack Width, W                | -     | m              |
| Stack Area, A                 | 0.16  | m <sup>2</sup> |
| Average stack gas temperature | 10    | °C             |
| Stack static pressure         | 0.145 | kPa            |
| Barometric Pressure           | 100.2 | kPa            |

| Stack Gas Composition & Molecular Weights |                 |                                   |                   |                          |                                     |                   |                          |                                     |
|-------------------------------------------|-----------------|-----------------------------------|-------------------|--------------------------|-------------------------------------|-------------------|--------------------------|-------------------------------------|
| Component                                 | Molar Mass<br>M | Density<br>kg/m <sup>3</sup><br>p | Conc Dry<br>% Vol | Dry Volume Fraction<br>r | Dry Conc<br>kg/m <sup>3</sup><br>pi | Conc Wet<br>% Vol | Wet Volume Fraction<br>r | Wet Conc<br>kg/m <sup>3</sup><br>pi |
| CO <sub>2</sub>                           | 44              | 1.963059                          | 0.028571          | 0.000286                 | 0.000561                            | 0.028215          | 0.000282                 | 0.000554                            |
| O <sub>2</sub>                            | 32              | 1.427679                          | 20.900000         | 0.209000                 | 0.298385                            | 20.639541         | 0.206395                 | 0.294666                            |
| N <sub>2</sub>                            | 28              | 1.249219                          | 79.071429         | 0.790714                 | 0.987775                            | 78.086030         | 0.780860                 | 0.975466                            |
| H <sub>2</sub> O                          | 18              | 0.803070                          | -                 | -                        | -                                   | 1.246213          | 0.012462                 | 0.010008                            |

Where:  $p = M / 22.41$   $pi = r \times p$

| Calculation of Stack Gas Densities          |        |                   |
|---------------------------------------------|--------|-------------------|
| Determinand                                 | Result | Units             |
| Dry Density (STP), $P_{STD}$                | 1.2867 | kg/m <sup>3</sup> |
| Wet Density (STP), $P_{STW}$                | 1.2807 | kg/m <sup>3</sup> |
| Dry Density (Actual), $P_{Actual}$          | 1.2296 | kg/m <sup>3</sup> |
| Average Wet Density (Actual), $P_{ActualW}$ | 1.224  | kg/m <sup>3</sup> |

Where:

$P_{STD}$  = sum of component concentrations, kg/m<sup>3</sup> (not including water vapour)

$P_{STW} = (P_{STD} + pi \text{ of H}_2\text{O}) / (1 + (pi \text{ of H}_2\text{O} / 0.8036))$

$P_{Actual} = P_{STD} \times (Ts / Ps) \times (Pa / Ta)$

$P_{ActualW} = P_{STW} \times (Ts / Ps) \times (Pa / Ta)$

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**PRELIMINARY STACK SURVEY**

**TRAVERSE 1**

|                              |                  |
|------------------------------|------------------|
| Date of Survey               | 15 December 2017 |
| Time of Survey               | 09:00            |
| Velocity Measurement Device: | S-Type Pitot     |

| Sampling Line A |                        |                                                     |                                     |         |              |                                                 |                         |                  |
|-----------------|------------------------|-----------------------------------------------------|-------------------------------------|---------|--------------|-------------------------------------------------|-------------------------|------------------|
| Traverse Point  | Distance into duct (m) | DP pt mmH <sub>2</sub> O<br>(average of 3 readings) | DP pt Pa<br>(average of 3 readings) | Temp °C | Velocity m/s | Volumetric Flow Rate (actual) m <sup>3</sup> /s | O <sub>2</sub> %<br>Vol | Angle of Swirl ° |
| 1               | 0.01                   | 51.7                                                | 506                                 | 10      | 24.1         | 3.8                                             | 20.9                    | <15              |
| 2               | 0.04                   | 52.3                                                | 513                                 | 10      | 24.3         | 3.9                                             | -                       | <15              |
| 3               | 0.07                   | 54.3                                                | 532                                 | 10      | 24.7         | 3.9                                             | -                       | <15              |
| 4               | 0.10                   | 55.7                                                | 546                                 | 10      | 25.0         | 4.0                                             | -                       | <15              |
| 5               | 0.15                   | 57.7                                                | 565                                 | 10      | 25.5         | 4.1                                             | -                       | <15              |
| 6               | 0.30                   | 59.7                                                | 585                                 | 10      | 25.9         | 4.1                                             | -                       | <15              |
| 7               | 0.35                   | 60.3                                                | 591                                 | 10      | 26.1         | 4.1                                             | -                       | <15              |
| 8               | 0.38                   | 58.3                                                | 572                                 | 10      | 25.6         | 4.1                                             | -                       | <15              |
| 9               | 0.41                   | 55.0                                                | 539                                 | 10      | 24.9         | 4.0                                             | -                       | <15              |
| 10              | 0.44                   | 53.0                                                | 519                                 | 10      | 24.4         | 3.9                                             | -                       | <15              |
| Mean            | -                      | 55.8                                                | 547                                 | 10      | 25.0         | 4.0                                             | 20.9                    | -                |

**PRELIMINARY STACK SURVEY QUALITY ASSURANCE CHECKLIST**

| PITOT LEAK CHECK |                        |              |              |         |                         |              |              |         |
|------------------|------------------------|--------------|--------------|---------|-------------------------|--------------|--------------|---------|
| Run              | Pre Traverse Leak Rate |              |              |         | Post Traverse Leak Rate |              |              |         |
|                  | Start Value Pa         | End Value Pa | Difference % | Outcome | Start Value Pa          | End Value Pa | Difference % | Outcome |
| Run 1            | 92                     | 91           | 1.1          | Pass    | 93                      | 93           | 0.0          | Pass    |

To complete a compliant pitot leak check a pressure of over 80 mmH<sub>2</sub>O (or 800 Pa) is applied and the pressure drop monitored over 5 mins. A drop of less than 5% must be observed.

| S-Type Pitot Stagnation Check |                 |                |                 |                               |
|-------------------------------|-----------------|----------------|-----------------|-------------------------------|
| Run                           | Stagnation (Pa) | Reference (Pa) | Difference (Pa) | Outcome (Permitted +/- 10 Pa) |
| Run 1                         | 138             | 138.5          | -0.5            | Pass                          |

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

**PRELIMINARY STACK SURVEY (CONTINUED)**

| Sampling Plane Validation Criteria             |        |       |             |           |
|------------------------------------------------|--------|-------|-------------|-----------|
| EA Technical Guidance Note (Monitoring) M1     | Result | Units | Requirement | Compliant |
| Lowest Differential Pressure                   | 506    | Pa    | >= 5 Pa     | Yes       |
| Lowest Gas Velocity                            | 24.1   | m/s   | -           | -         |
| Highest Gas Velocity                           | 26.1   | m/s   | -           | -         |
| Ratio of Gas Velocities                        | 1.1    | -     | < 3 : 1     | Yes       |
| Maximum angle of flow with regard to duct axis | <15    | °     | < 15°       | Yes       |
| No local negative flow                         | Yes    | -     | -           | Yes       |

| Calculation of Stack Gas Velocity, V                                                                                                     |      |     |
|------------------------------------------------------------------------------------------------------------------------------------------|------|-----|
| Velocity at Traverse Point, $V = K_{pt} \times (1-e) \times \sqrt{2 \times DP_{pt} / \rho_{ActualW}}$                                    |      |     |
| <b>Where:</b><br>$K_{pt}$ = Pitot tube calibration coefficient<br>(1-e) = Compressibility correction factor, assumed at a constant 0.998 |      |     |
| Average Stack Gas Velocity, $V_a$                                                                                                        | 25.0 | m/s |

| Calculation of Stack Gas Volumetric Flowrate, Q |         |           |       |
|-------------------------------------------------|---------|-----------|-------|
| Duct gas flow conditions                        | Actual  | Reference | Units |
| Temperature                                     | 10      | 0         | °C    |
| Total Pressure                                  | 100.345 | 101.3     | kPa   |
| Oxygen                                          | 20.9    | 21        | %     |
| Moisture                                        | 1.25    | 1.25      | %     |
| Pitot tube calibration coefficient, $K_{pt}$    | 0.84    |           |       |

| Gas Volumetric Flowrate                           | Result | Units              |
|---------------------------------------------------|--------|--------------------|
| Average Stack Gas Velocity ( $V_a$ )              | 25.05  | m/s                |
| Stack Area (A)                                    | 0.16   | m <sup>2</sup>     |
| Gas Volumetric Flowrate (Actual), $Q_{Actual}$    | 14343  | m <sup>3</sup> /hr |
| Gas Volumetric Flowrate (STP, Wet), $Q_{STP}$     | 13706  | m <sup>3</sup> /hr |
| Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$ | 13535  | m <sup>3</sup> /hr |
| Gas Volumetric Flowrate (REF), $Q_{Ref}$          | 13706  | m <sup>3</sup> /hr |

**Where:**

$$Q_{Actual} = V_a \times A \times 3600$$

$$Q_{STP} = Q_{Actual} \times (T_s / T_a) \times (P_a / P_s) \times 3600$$

$$Q_{STP,Dry} = Q_{STP} / (100 - (100 / Ma)) \times 3600$$

$$Q_{Ref} = Q_{STP} \times ((100 - Ma) / (100 - Ms)) \times ((20.9 - O_{2a}) / (20.9 - O_{2s}))$$

**Nomenclature:**

$T_s$  = Absolute Temperature, Standard Conditions, 273 K

$P_s$  = Absolute Pressure, Standard Conditions, 101.3 kPa

$T_a$  = Absolute Temperature, Actual Conditions, K

$P_a$  = Absolute Pressure, Actual Conditions, kPa

$Ma$  = Water vapour, Actual Conditions, % Vol

$Ms$  = Water vapour, Reference Conditions, % Vol

$O_{2a}$  = Oxygen, Actual Conditions, % Vol

$O_{2s}$  = Oxygen, Reference Conditions, % Vol

### STACK DIAGRAM

Sampling Line

[illegible]

APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER**

| Run                | Sampled Volume<br>m <sup>3</sup> | Sampled Gas Temp<br>K | Sampled Gas Pressure<br>kPa | Sampled Gas Humidity<br>% by volume | Oxygen Content<br>% by volume | Limit of Detection<br>% by mass | Leak<br>%   | Uncollected Mass<br>mg |
|--------------------|----------------------------------|-----------------------|-----------------------------|-------------------------------------|-------------------------------|---------------------------------|-------------|------------------------|
| <b>MU required</b> | <b>≤ 2%</b>                      | <b>≤ 2%</b>           | <b>≤ 1%</b>                 | <b>≤ 1%</b>                         | <b>≤ 10%</b>                  | <b>≤ 5% of ELV</b>              | <b>≤ 2%</b> | <b>≤ 10% of ELV</b>    |
| Run 1              | 0.001                            | 2.0                   | 0.50                        | 1.0                                 | N/A                           | 0.5000                          | -           | -                      |
| as a %             | 0.08                             | 0.71                  | 0.50                        | 1.0                                 | N/A                           | 3.76004                         | 0.64        | 0.006                  |
| <b>compliant?</b>  | <b>Yes</b>                       | <b>Yes</b>            | <b>Yes</b>                  | <b>Yes</b>                          | <b>N/A</b>                    | <b>Yes</b>                      | <b>Yes</b>  | <b>Yes</b>             |

| Run                     | Volume (STP)<br>m <sup>3</sup> | Mass of particulate<br>mg | O <sub>2</sub> Correction<br>- | Leak<br>mg/m <sup>3</sup> | Uncollected Mass<br>mg | Combined uncertainty |
|-------------------------|--------------------------------|---------------------------|--------------------------------|---------------------------|------------------------|----------------------|
| Run 1                   | 1.25                           | 0.5000                    | 1.0                            | 0.001                     | 0.0003                 | -                    |
| MU as mg/m <sup>3</sup> | 0.00                           | 0.3760                    | -                              | 0.001                     | 0.0003                 | <b>0.38</b>          |
| MU as %                 | 1.32                           | 100.0000                  | -                              | 0.369                     | 0.0693                 | -                    |

|                                                                           |             |                         |               |          |
|---------------------------------------------------------------------------|-------------|-------------------------|---------------|----------|
| <b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b> | <b>0.75</b> | <b>mg/m<sup>3</sup></b> | <b>200.02</b> | <b>%</b> |
|---------------------------------------------------------------------------|-------------|-------------------------|---------------|----------|

(k is a coverage factor which gives a 95% confidence in the quoted figures)

Reference – SOCOTEC UK Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - OIL MIST**

| Run                | Sampled Volume<br>m <sup>3</sup> | Sampled Gas Temp<br>K | Sampled Gas Pressure<br>kPa | Sampled Gas Humidity<br>% by volume | Oxygen Content<br>% by volume | Concentration in impinger<br>mg | Leak<br>%      |
|--------------------|----------------------------------|-----------------------|-----------------------------|-------------------------------------|-------------------------------|---------------------------------|----------------|
| <b>MU required</b> | <b>&lt;=2%</b>                   | <b>&lt;2.5 k</b>      | <b>&lt;=1%</b>              | <b>&lt;=1%</b>                      | <b>&lt;=5%</b>                | <b>&lt;5%</b>                   | <b>&lt;=2%</b> |
| Run 1              | 0.001                            | 2.0                   | 0.50                        | 1.0                                 | 0.10                          | -                               | -              |
| as a %             | 0.08                             | 0.73                  | 0.49                        | 1.0                                 | -                             | -                               | 0.64           |
| <b>compliant?</b>  | <b>Yes</b>                       | <b>Yes</b>            | <b>Yes</b>                  | <b>Yes</b>                          | <b>N/A</b>                    | <b>No</b>                       | <b>Yes</b>     |

| Run                     | Volume (STP)<br>m <sup>3</sup> | O2 Correction<br>- | Mass of Heavy Metals<br>mg | Leak<br>mg/m <sup>3</sup> | Lab Uncertainty<br>mg | Combined uncertainty |
|-------------------------|--------------------------------|--------------------|----------------------------|---------------------------|-----------------------|----------------------|
| Run 1                   | 1.3331                         | -                  | 200.0000                   | 0.0006                    | -                     | -                    |
| MU as mg/m <sup>3</sup> | 0.0020                         | -                  | 0.0752                     | 0.0006                    | 0.01504               | <b>0.0767</b>        |
| MU as %                 | 1.3359                         | -                  | 50.0000                    | 0.3688                    | 10.00000              | -                    |

|                                                                           |             |                         |               |          |
|---------------------------------------------------------------------------|-------------|-------------------------|---------------|----------|
| <b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b> | <b>0.15</b> | <b>mg/m<sup>3</sup></b> | <b>102.02</b> | <b>%</b> |
|---------------------------------------------------------------------------|-------------|-------------------------|---------------|----------|

(k is a coverage factor which gives a 95% confidence in the quoted figures)

Reference – SOCOTEC UK Technical Procedure AE150 Estimation of Uncertainty of Measurement

APPENDIX 3 - Measurement Uncertainty Budget Calculations

**MEASUREMENT UNCERTAINTY BUDGET - MOISTURE**

| Run                | Sampled Volume<br>m <sup>3</sup> | Sampled Gas Temp<br>K | Sampled Gas Pressure<br>kPa | Sampled Gas Humidity<br>% by volume | Oxygen Content<br>% by volume | Leak<br>%   |
|--------------------|----------------------------------|-----------------------|-----------------------------|-------------------------------------|-------------------------------|-------------|
| <b>MU required</b> | <b>≤ 2%</b>                      | <b>≤ 2%</b>           | <b>≤ 1%</b>                 | <b>≤ 1%</b>                         | <b>≤ 10%</b>                  | <b>≤ 2%</b> |
| Run 1              | 0.001                            | 2.0                   | 0.50                        | 1.0                                 | N/A                           | -           |
| as a %             | 0.08                             | 0.71                  | 0.50                        | 1.0                                 | N/A                           | 0.64        |
| <b>compliant?</b>  | <b>Yes</b>                       | <b>Yes</b>            | <b>Yes</b>                  | <b>Yes</b>                          | <b>N/A</b>                    | <b>Yes</b>  |

| Run         | Volume (STP)<br>m <sup>3</sup> | Mass Gained<br>mg | O <sub>2</sub> Correction<br>- | Leak<br>mg/m <sup>3</sup> | Uncollected Mass<br>mg | Combined uncertainty |
|-------------|--------------------------------|-------------------|--------------------------------|---------------------------|------------------------|----------------------|
| Run 1       | 1.25                           | 13300             | 1.0                            | 37.35                     | 58                     | -                    |
| MU as % v/v | 0.02                           | 0.01              | -                              | 0.00                      | 0.006                  | <b>0.02</b>          |
| MU as %     | 1.32                           | 0.75              | -                              | 0.37                      | 0.43                   | -                    |

|                                                                           |             |              |             |          |
|---------------------------------------------------------------------------|-------------|--------------|-------------|----------|
| <b>R1 - Uncertainty expressed at a 95% confidence level (where k = 2)</b> | <b>0.04</b> | <b>% v/v</b> | <b>3.25</b> | <b>%</b> |
|---------------------------------------------------------------------------|-------------|--------------|-------------|----------|

**MEASUREMENT UNCERTAINTY BUDGET - VELOCITY & VOLUMETRIC FLOW RATE**

|                                                    |       |                    |
|----------------------------------------------------|-------|--------------------|
| Measured Velocity at Actual Conditions             | 25.0  | m/s                |
| Measured Volumetric Flow rate at Actual Conditions | 14343 | m <sup>3</sup> /hr |

| Performance Characteristics & Source of Value                 | Units      | Values  | Requirement                                | Compliant |
|---------------------------------------------------------------|------------|---------|--------------------------------------------|-----------|
| Uncertainty of Local Gas Velocity Determination               |            |         |                                            |           |
| Uncertainty of pitot tube coefficient                         | -          | 0.010   |                                            |           |
| Uncertainty of mean local dynamic pressures                   | -          | 0.60    |                                            |           |
| Factor loading, function of the number of measurements.       | 3 readings | 0.591   | minimum 3                                  | Yes       |
| Range of measurement device                                   | pa         | 1000    |                                            |           |
| Resolution                                                    | pa         | 1.00    |                                            |           |
| Calibration uncertainty                                       | pa         | 10.00   | <1% of Value or 20 Pa whichever is greater | Yes       |
| Drift                                                         | % range    | 0.10    |                                            |           |
| Linearity                                                     | % range    | 0.06    | <2% of value                               | Yes       |
| Uncertainty of gas density determination                      |            |         |                                            |           |
| Uncertainty of molar mass determination                       | kg/mol     | 0.00003 |                                            |           |
| Uncertainty of temperature measurement                        | K          | 1.44    | <1% of value                               | Yes       |
| Uncertainty of absolute pressure in the duct                  | pa         | 512     |                                            |           |
| Uncertainty associated with the estimate of density           | -          | 0.007   |                                            |           |
| Uncertainty associated with the measurement of local velocity | -          | 0.0001  |                                            |           |
| Uncertainty associated with the measurement of mean velocity  | -          | 0.0002  |                                            |           |

|                                                   |            |
|---------------------------------------------------|------------|
| <b>Measurement Uncertainty - Velocity</b>         | <b>m/s</b> |
| Combined uncertainty                              | 0.31       |
| Expanded uncertainty at a 95% Confidence Interval | 0.61       |

Note - The expanded uncertainty uses a coverage factor of k = 2.

|                                                                                  |          |
|----------------------------------------------------------------------------------|----------|
| <b>Expanded Measurement Uncertainty of Velocity at a 95% Confidence Interval</b> | <b>%</b> |
| Expressed as a % of the Measured Velocity                                        | 1.2      |
| Expanded uncertainty at a 95% Confidence Interval                                | 2.4      |

|                                                     |                         |
|-----------------------------------------------------|-------------------------|
| <b>Measurement Uncertainty Volumetric Flow Rate</b> | <b>m<sup>3</sup>/hr</b> |
| Combined uncertainty                                | 376                     |
| Expanded uncertainty at a 95% Confidence Interval   | 737                     |

Note - The expanded uncertainty uses a coverage factor of k = 2.

|                                                                                              |          |
|----------------------------------------------------------------------------------------------|----------|
| <b>Expanded Measurement Uncertainty of Volumetric Flow Rate at a 95% Confidence Interval</b> | <b>%</b> |
| Expressed as a % of the Measured Volumetric Flow Rate                                        | 2.6      |
| Expanded uncertainty at a 95% Confidence Interval                                            | 5.1      |

Reference – SOCOTEC UK Technical Procedure AE150 Estimation of Uncertainty of Measurement

## END OF REPORT

*Thank you for choosing SOCOTEC UK for your environmental monitoring needs. We hope our services have met your requirements and that you are fully satisfied with your experience of working with us, we really do value your custom and would welcome your feedback. We would appreciate it if you could take a moment to complete a short online questionnaire so that we can improve our operations and address any areas that have not met with your expectations, by clicking on the following*

[https://www.surveymonkey.co.uk/r/CAE\\_customer\\_feedback\\_weblink](https://www.surveymonkey.co.uk/r/CAE_customer_feedback_weblink)